

# Technology-Enhanced Learning (TEL) Tools to Improve Computational Thinking Skills

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**Abstract**— The common and easy access to technological devices has led to the rapid inclusion of technology into the learning process. The development of technical skills, as well as the increasing confidence in computer attitudes, seems to be obvious. We therefore propose to go beyond and advocate the use of TEL to provide specific leadership, multi-tasking and other organizational skills, known as computational thinking, as precisely the main contributions provided by TEL.

To support this hypothesis, we present two different experiences. The first, based on high-school students, to introduce young people to technology at the same time as they acquire other demanding skills. The second, with undergraduate Computer Science students, is focused on technology itself to enhance and improve computational thinking skills. A comparison is also made between two populations with different digital profiles in their user skills (general in the first case and engineering biased in the second).

**Keywords**—component; TEL; computational thinking; learning tools; collaborative learning; technical degrees.

## I. INTRODUCTION

Common and easy access to technological devices has led to the rapid inclusion of technology into the learning process at all stages and in all situations (schools, universities, life-long learning). Development of technical skills, as well as increasing confidence in computer attitudes, supports these assumptions. In this context, Technology-Enhanced Learning (TEL), representing the technological support of any pedagogical approach, is a highly active research field today.

TEL represents an alternative in the acquisition of knowledge that adapts very well to current students [1] and favors the learning process; some consequences are a better attention on the part of the learner and an increasing dynamism in the process [2].

Furthermore, as a consequence of using technology, TEL helps students to develop and reinforce specific skills such as leadership, multi-tasking and other organizational skills, together known as computational thinking [3].

Computational thinking is a kind of analytical thinking, based on abstraction, not exclusive to computers but more

powerful and necessary in nearly all disciplines, both in the sciences and the humanities. As an example, the use of online tools, usually shared between several components of the group, who agree to:

- Subdivide the problem into simpler subproblems.
- Establish effective communication between members of the group.
- Make a good planning of tasks.
- Mark teamwork strategies for the management to be as efficient as possible.
- Work to merge all information collected and elaborated in several documents.

And all the above strategies correspond to the characteristics that, according to [4], should form part of an activity that promotes computational thinking in students.

In this paper, we advocate the use of TEL to provide computational thinking, precisely as its main contribution, especially in ICT degrees.

It is in this ICT context that we present two different experiences, one at High-school level and another in a Computer Science undergraduate course. Both are examples of development and improvement in computational skills, though the first is in a more general context.

In the first group, the High-school students, the activity described is based on the integration of skills in the curriculum of compulsory secondary education that causes a shift in the teaching methodology applied in the classroom. Among these skills we can find: digital, learn to learn, and personal autonomy. The use of technology as a learning tool in the classroom reinforces computational thinking and enhances the acquisition of these skills.

The activity is defined and implemented, for students in the 1st year of ESO (compulsory secondary education). It is essential to develop computational thinking skills at early ages, since are already undertaken and integrated into the mindset of students at higher levels.

The activity consists of an interdisciplinary work where research is conducted around an initial question. This work is performed in groups during a school week. Students learn to organize their work and their way of structuring the final results in terms of these different tools, by integrating the different ways of working in a single result.

For the second group, undergraduate Computer Science students, TEL use is focused on technology itself as a tool to enhance and improve their already acquired computational thinking skills.

As future developers of Software projects, Computer Science undergraduates should learn to work in interdisciplinary professional teams (software experts, problem-to-solve area experts or company staff) and should also develop products that persist over time with updates, modifications and extensions by other people not present at startup.

A set of tools integrating these communication and maintenance skills is developed and tested for a semester.

A comparison is also made between the two populations based on the digital profiles they show in their everyday life and their professional skills (general in the first case and engineering biased in the second). It is very interesting to observe that, in agreement with [5], there is no unified profile for young people as “digital natives”, and no assumption can be made from the day-to-day technological use to be applied in the classroom as an acquired skill.

The rest of the document is organized as follows: in Section II and Section III we explain the two cases of study and the results observed in both cases. In Section IV we present some related work of TEL tools applied to higher education. Section V contains conclusions and proposed future work; and finally, the Acknowledgement and Bibliography Sections are presented.

## II. FIRST CASE STUDY: ORGANIZING PEGASSUS PARK

The case study presented in this paper has been possible by the development of the “School 2.0” program in Spain, as a result of about EC initiatives to encourage the use of ICT in compulsory education. The “School 2.0” program is defined in different ways in the Spanish autonomous communities. In the case of Catalonia, the autonomous government decided to invest in a model of personal computer for each student individually. This decision promotes the development of activities where the use of ICT is done intensively.

Furthermore, the curriculum of the Catalan autonomous government included in each year of compulsory secondary an interdisciplinary work where research is conducted around an initial question. This work is performed in groups during a school week.

Taking advantage of the fact that the students had personal computers, this research work was designed to do using only computer tools.

The goals to achieve by the end of the activity were:

- Provide students with strategies to work in collaborative groups.
- Training in the use of ICT tools that enable the development of the collaborative group work.
- Promote personal autonomy with regard to research.
- Develop computational thinking applied to problem solving in environments near students.
- Establish strategies for managing individual and group work.

We used the learning platform Moodle. This tool allows not only access to the information you want to be accessible to the students, but also provides a control over the activities undertaken [6].

The student activities were performed using Web 2.0 collaborative tools and students were forced to manage their organization and their way to structure the final result in terms of the tools [7]. These tools were: Google Docs (text and spreadsheet), Prezi (for presentations), Woices (effecting geopositioned audio guide), Gmail (in communication) and QR code generators.

The activity starts from the question “how a public park should be managed?” The secondary school where this activity is applied is next to a park of considerable size and a very popular place in the neighborhood, familiar to students, so a more extensive knowledge about its management would enable them to be aware of the need for a good use of that environment. Furthermore, in this way, students could exercise social and citizenship skills, and knowledge of the physical environment.

To initiate the work, students were required to carry out a survey on the use of the park, considering the visitors age and sex. Questions included in this survey were, for example, frequency of visits to the park, most frequently park areas visited, or solo visits or accompanied. The final survey data were collected on a spreadsheet and graphs drawn according to the different age ranges. Finally, conclusions were reported.

As a final outcome, the students had to generate four documents in different formats. These documents contained the information gathered from several ICT tools, which therefore had to be organized in a specific way depending on the objective and the characteristics of the tool itself. The final products are:

- A written report which contains the most relevant data about the initial research question and the final conclusions. This report is elaborated collaboratively through Google Docs and has different elements: photographs (taken by the students and computer processed) and graphics made with the spreadsheet. The report also allows the attainment of the communicative and mathematical competences.
- A multimedia presentation of the information and the conclusion using the application Prezi. This application allows, in the same ways as Google Docs, for collaborative work, and, thus, all the group members

can contribute, as it is a shared file. The multimedia presentation also allows for the attainment of the communicative and mathematical competences as well as the artistic and cultural ones.

- An informative guide on paper, which had to contain the main characteristics of the park studied by the pupils. This guide included written material (in three languages), graphic material and QR codes associated to a blog showing the main characteristics of the different types of vegetation found in the park. The QR codes are accessible by intelligent mobiles with access to an application capable of reading the codes. The competences achieved through the elaboration of the guide include the communicative and audiovisual competences, as well as the artistic, social and citizenship ones.



Figure 1. An example of an leaflet guide, including the map, QR code and English explanation (in the other page they are Spanish and Catalan text).

- A geo-positioned audio guide elaborated with the application Woices. The most relevant spaces of the park were described aurally and associated to images taken by the students themselves. This audio guide can be listened to through intelligent mobiles with access to the application (freeware). Through this process the students attained the communicative, audiovisual, artistic and cultural competences.

Figure 2. Four different auto-guides created by students.



## A. Applying Computational Thinking

In order to facilitate the division of the initial problem into more specific work areas, the information was structured into different topic blocks in the platform. Each block contained, besides the corresponding information, the necessary links and the activity submission deadlines. Each group decided the order and the methodology of work for each block. It must be noted that some information included in a block could be necessary in another work and that some of the conclusions became the basis for another related problem.

The division into blocks allowed for the establishment of process diagrams to structure the procedure for the solution of the global problem. The use of process diagrams is one of the methodological strategies that facilitate computational thinking as they establish the sequence of the operations that have to be done and show the relationship among them.

As to the work methodology, the students were divided into groups of 4 or 5 members. The group management had to be reached through consensus by all the members, and all of them had to contribute to the final documents. The work with collaborative 2.0 tools allowed each member to generate information as well as revise and correct that of their peers. This collaborative part implies synchronization between members' updates in order to keep information.

## B. Results

With the objective of assessing the activity, taking into account both its development and the degree of satisfaction of the agents involved (teachers and students), a survey was carried out.

As to the students' answers, most of them (85%) rated very positively the methodology of work, which they considered more motivating than traditional methodology. Nevertheless, some comments point out the problems encountered in terms of group management and time organization. These problems are due to lack of training in collaborative group work both on the part of the students and the teachers.

As to the teachers' answers, the activity was also rated positively by the majority (80%). The main problems highlighted by the teachers refer to their lack of confidence in their own computer skills, and the consideration that the students are superior to them in terms of ICT skills. As the students, they define this learning experience as more motivating and competence rising for the student, although they add as a negative aspect the great amount of dedication needed in the preparation and follow-up stages.

The main negative aspect during the development of the activity was the problems in the connection to the Internet. It is absolutely necessary to have a broad band and fast Internet connection.

As an accessory result, it has been noted that mobile phones have great potential in distance learning. The concept of m-learning was applied to some of the activities carried out by the students (audio guide and QR codes), with satisfactory results. This is one of the fields, which should be studied in terms of its possibilities of use and application in education [8].

### III. SECOND CASE STUDY: OPERATING SYSTEMS PROJECTS

Different studies propose the use of TEL as a support to learn Computer Science attracting students and reinforcing Computer Science knowledge and skills. In general TEL is considered an effective learning alternative that improves contact with technology; in this specific field, it also allows the user to create code and provide examples and exercises that improve students' basic understanding and immediate feedback.

Five are the skills considered peculiar to the Computer Science area [9] and these are: Programming, Interoperability, Operating Systems, Data Bases and Data Modeling. For this reason we choose as a very suitable subject for us case study the Operating Systems for Distributed Applications (OSDA).

Based on the Bologna curriculum, OSDA is a subject in the third course in the Computer Science School (FIB) at UPC. The goals as described in the curriculum are: Intensification of the OS basic concepts, focusing on performance and efficiency of distributed applications such as databases, search engines, or web-based applications. Management resource strategies will be extended to new levels such as runtime, middleware or libraries.

The course is designed for practical work that students should develop in the lab sessions, resting on a theoretical basis developed in classes organized and directed by the teacher and the active participation of students. The practical experiments will be limited initially to facilitate achievement of objectives and then apply all the knowledge necessary to optimize a particular situation or assess the impact of different solutions, implementations and policies. At the end of the course, groups of 3-4 students will present a case study.

Two key learning skills in this context are:

- Organizing information for the study, modification, addition or expansion of the contents in an organic and comprehensible way.
- Communicating and sharing information so that content can be added simultaneously.

From each of these objectives the students learn specific Computer Engineer skills:

- Through organizing information, they learn about scalability of solutions, dividing problems into subproblems, searching process performance and process automation.
- Through communicating and sharing information, they learn event synchronization and concurrency management.

All the above skills are related computational thinking as explained in Section I. The set of tools chosen is based on the

different activities we prepared, taking into account the familiarity that students, as digital natives, would have acquired outside of classes. The following subsections explain each one in more detail.

#### A. Already acquired concepts and abilities training

The OSDA syllabus is mainly based on contents from previous courses, so the first step is to reinforce the already acquired concepts. This is also our opportunity to practice the students' digital-tool knowledge in an academic environment. To this end, some reports containing the previous main concepts and some basic exercises are provided. For each basic block, an auto-assessment quiz is provided.

This part is basically a training part, and the students agree on its use through a web scheme: we use ATENEA, a Moodle-based framework for UPC internal use [10]. The activities and material provided are focus on reviewing already known concepts and on practicing programming skills. The students have documents and several self-assessment quizzes (true/false, multiple-choice, short answers) are used; the solutions are provided at the end to allow them to learn from their own mistakes.

To go a step further, videos providing some "how-to" program (i.e. how to program a Linux kernel Module (LKM)), enable students to reproduce the work and try to do their first LKM. Then, it is possible to change some characteristics and build a new, modified LKM.

The teacher is able to supervise all this training, because activity reports and results are stored for each participant, so it is possible to give advice and to improve learning by adapting future classes to the student level.

Sistemas Operatius per Aplicacions Distribuïdes (Curs Total)

Info Results Preview Edit

Preview Student Self-Questionnaire

Start again

1 El contador de referencias de un módulo sirve para asegurar que un proceso no lo utiliza más de una vez.

Marks: --/1

Choose one answer.

☐ a. Falso

☐ b. Verdadero

Submit

2 Els LKM formen part del codi de kernel però s'executen en mode usuari.

Marks: --/1

Answer:

☐ Verdader

☐ Fals

Submit

Figure 3. Example of questions in the self-assessment quiz provided before the course topic to remember previous definitions and characteristics.

This part is performed by the students individually and by their own, and results show that 100% of students used these tests satisfactorily.



Figure 4. The introductory Moodle-based web containing the reports and exercises.

### B. Wiki

Collaborative learning, as part of the skills provided by computational thinking, is one of the methodologies that can provide TEL tools. We consider it necessary to give more attention to collaborative work to really develop this skill, which is a required attitude, especially in ICT professional areas. So, it is necessary to promote learning based on problem-solving approaches and taking advantage of the potential that TEL tools provide.

It is attractive for students to have the chance to create contents in an organized way, with a support that allows them to share and collaborate in adding information. Wikis are a tried and tested way of doing this (i.e. Wikipedia). Students have to decide how to divide the work, so that different students or groups are able to write and to build pages and contents without interfering with others, if possible. This division of work is not unique, but differences may lead to a better or worse result. This was a practical test about divide-and-conquer techniques, because the different code parts come after the documentation.



Figure 5. The Google-site web, as a wiki for students to introduce and manage information.

The tool used was Google sites, a very intuitive easy-to-use website. Four teams of four people manage different parts and subjects to introduce into the wiki; all the students can even contribute and participate in all of the different parts. In this way, they also have to arrive at an agreement about a specific website format for presentation of contents and to navigate through it following a coherent pathway.

### C. Results

The auto-assessment quiz is a

Build a wiki with the contents they were learning was not easy or quick. The main problem we faced was to start writing content on a completely blank page, and from there, guiding all the structure and hierarchy of a web page itself. Initially, it was a repository of documents without any organization or specific classification; so, we provided some basic inputs to make the filling easier: a first title, the first sentence and some basic bullets (representing future links to new pages).

Surprisingly for us, students have not yet acquired familiarity of moving from one to another tool: going through three different webs to perform the work was a difficulty for them, who felt an extra complexity to have to distinguish in what case should be use one or another work environment. This highlighted the lack of flexibility in the regular use of technological tools and the difficulty to get out of their familiar environment. We realized that this generation of students, acquainted with ICT, has a hands-on ability but still have to acquire an intellectual, too.

The reluctance to share information and work more openly from the start, with members of other groups also was a surprise to teachers, who assumed a habitual communication by Internet among students.

## IV. RELATED WORK

In our approach, we propose a set of tools and the corresponding strategies to connect them, so that different learning methods can be applied. Our interest is to practice and improve intellectual more than technical skills, but through technical tools.

There are several learning methods with the goal to develop and reinforces skills by using technological in ICT degrees. Some of these skills are for example:

- Interiorize the skills to solve problems using techniques such as divide-and-conquer, and then be able to apply them in a variety of situations in real life. Here there are jigsaw techniques [11].
- Be creative in the way to present results and explanations, using multimedia or graphical tools.
- Improve writing skills, modifying and improving lecture notes using wikis [12].
- Collaborate by using social networks (Twitter [13] or microblogs in general [14]) or other Internet tools (i.e. joinme) or specific oriented platforms [15].



All these abilities are needed to collaborate, share knowledge and presenting results to others.

Obviously, all proposed technical tools as video tutorial, animations, etc. can be used and included in such a framework, based on the activity to build. However, the underlying idea is to simplify the hand-on material and to reinforce the activities related with computational thinking. In this way we facilitate the learning process and make it faster, without paying too much attention to the tools and the way to use them. All this by focusing in the specific activities that improve and develop computational thinking aptitudes needed for professional excellence.

## V. CONCLUSIONS

Computational thinking provides a way to solve real problems based on abstraction and division of the main problem into subproblems more easily analyzed. These skills are applicable to any professional field, so we consider important to develop activities and use tools that support it from an early age. While any profession may benefit from the acquisition of these skills, they are especially important for future engineers.

The use of TEL in high school and later in university education, by their nature, favors developing computational thinking.

The different attitude towards the use of technology in learning has made us think about the different skills and habits in the "digital generation" among young people in two different age ranges: 13-16 years old some and 20-22 others, as well as the differentiation made between digital use in their social life and in their way of learn and work.

The middle-school activity implementation and execution showed that they had greater adoption to TEL tools and motivation in their use. Students were able to investigate, test and produce by their own. For undergraduate students, this adaptation was smaller and, in some cases, they couldn't move fluidly through the application without an external motivation.

That is why we believe the use of TEL tools should be implemented at an early age in order to achieve these skills gradually through their academic instruction.

The development of digital competence together with computational thinking, will favor the use and benefits of ICT in education to enhance learning and to enhance skills like learning to learn, abstraction, personal autonomy and self-strategies to solve real-based problems.

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